Agricultural Extension Service
University of Minnesota



Extension Folder 428
(Formerly Special Report 64—1977)



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In Minnesota, and much of the Corn Belt, the chisel plow and large disk are challenging the moldboard plow as the tools for primary tillage. The current variety in tillage equipment allows flexibility and can create a wide range of soil conditions. Continuous use of one tillage system tends to magnify its deficiencies. Many farmers who use a chisel or large disk have kept their moldboard plow to vary tillage to fit current crop, soil, and water conditions on their farms.

Any successful tillage system must prepare a satisfactory seedbed for a specific crop; the size of aggregates, soil temperature, soil water content, and soil density must be within a range favorable for germination and early growth.

Moldboard plowing, chisel plowing, and disking produce different aggregate sizes, incorporate different amounts of residue and surface-applied material (chemicals, crop residue, weed seeds), and operate over somewhat different ranges in water contents. Overwinter weathering and secondary tillage modify the top part of the tilled layer, reducing the effect of primary tillage on aggregate size. Repeated secondary tillage tends to produce similar seedbed conditions, regardless of whether a plow, chisel, or disk was used. However, incorporation of residue and depth of mixing of surface-applied chemicals will be less complete after chisel or disk plowing than after moldboard plowing, even after repeated secondary tillage operations.

## Choosing between the moldboard plow, chisel, and disk

Selection of the tillage system has to be based on cropping patterns, soil needs in terms of protection from erosion and fertility requirements, pesticide application needs, energy and time budgets, and expected soil water level at tillage time. Each factor may dictate some soil manipulation, or lack of it, and require compromises. Personal experience and preference certainly affect the choice and provide a farm operator with knowledge or incentive for success with a particular system.

## Residue management

Tillage for cropping needs should deal with the old crop residues and soil structure so the planter will operate successfully and satisfactory seedbed conditions will result. Light residues from soybeans, small grain, and corn harvested as silage require little tillage to allow planting a succeeding crop.

After corn, as much as 3 or 4 tons of residue per acre may be left in the field. One operation of the disk or chisel plow leaves about 60 percent of the residue on the surface or up to 2-2½ tons/acre (T/A). Each ton of cornstalk mulch decreases average 4-inch spring soil temperature about ¾°F. The amount of mulch which can be safely left on the surface depends on the natural drainage class of the soil and will be discussed later. The chisel incorporates surface material less deeply than a moldboard plow. In a year at Waseca when above-normal amounts of corn were left in the field after harvest, volunteer corn in soybeans following chisel plowing was about double that following moldboard plowing or double disking.

In very dry years, herbicide carryover and crop damage is more likely after disk or chisel plowing than after moldboard plowing. Moldboard plowing inverts the tilled layer, mixes residue with the soil, and lowers the concentration of residue near the soil surface.

Levels of surface mulch have had little effect on corn yield on well-drained soils, but on poorly drained soils, mulch levels are much more critical. Surface mulch levels of about 2 T/A of cornstalks remaining after chisel plowing had little or no effect on corn yields on a somewhat poorly drained clay loam soil at Waseca, even though early corn growth was reduced about twenty percent. However, a 4 T/A level of mulch after no-till resulted in a 10 bushel per acre (Bu/A) yield reduction on this same soil and a 50 percent reduction in early growth. On poorly and very poorly drained soils, 2 tons of cornstalk residue is excessive because reductions in early corn growth and corn yield are more likely with a surface mulch than on better-

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drained soils. On poorly drained soils, little or no surface mulch is desired. Some farmers have reduced the problems by disking poorly drained soils, before chiseling, to incorporate more of the residue. Soybean yields have been affected less by mulch levels and type of tillage than corn yields.

### Soil type

On poorly drained soils, fall tillage has shown yield increases over spring plowing and will provide warmer, drier soil conditions at planting. On well-drained soils, tillage may be delayed until spring when one or two shallow tillage operations will produce a seedbed for either corn or soybeans.

Research results indicate that to create a satisfactory seedbed on clay loam and finer-textured soils, more spring secondary tillage operations may be necessary after fall chisel than after fall moldboard plowing. Observations at Waseca support those at Iowa where greater difficulty was experienced in preparing an adequate seedbed with chisel plowing than with moldboard plowing where corn followed corn. Such problems are much less likely on silt loam and coarser-textured soils, or when corn follows soybeans.

Since a chisel relies on shattering action to break up soil, a chisel may require somewhat drier soil conditions than a moldboard plow for satisfactory operation. This problem can be partly overcome by substitution of "duck-

**The chisel plow leaves a rough soil surface and leaves residue on the surface.**

**The moldboard plow is preferred for deep incorporation of surface material.**

foot'' sweeps for chisel points, and shallower operation which allows the chisel plow to be used under wetter soil conditions.

### Erosion control and water conservation

Tillage systems can provide erosion control and water conservation in the following ways:

- Systems that leave the surface rough and porous or create ridges at right angles to the slope effectively increase infiltration and decrease runoff. The rough surface slows the velocity of runoff and allows more time for infiltration. The effectiveness of the rough surface decreases during the season.

- Systems that leave large portions of the soil surface covered with residues offer protection from raindrop detachment of soil particles and surface sealing which limits water intake. The residues serve as barriers to runoff, decreasing its velocity, and allowing more time for infiltration. Systems that rely on surface residues for protection are likely to maintain their effectiveness for a longer time than those dependent on soil roughness.

Both the chisel and the disk plow leave crop residue on the surface which helps protect against wind and water erosion. However, the disk plow pulverizes the soil more thoroughly and leaves a smoother surface than the chisel plow. The rougher surface left by the chisel plow increases infiltration and lessens wind and water erosion. Observations indicate that chisel-plowed soybean land suffered much less from wind erosion than fall plowed during the 1975-76 winter. The chisel plow can be very effective in reducing water erosion where the rough surface left by the chisel plow is protected by adequate mulch. Research in western Minnesota by the USDA, ARS from Morris, Minnesota, has demonstrated the effectiveness of the chisel plow in reducing runoff. When 1,200 pounds of small grain residue was left on the surface after fall chiseling, almost seven inches of artificial rainfall was applied the following spring before any runoff occurred. At the same time, on a fall-plowed surface, runoff began after only 1.2 inches of water was applied.

Illinois studies showed that conservation tillage systems significantly reduced soil loss. After a 4-inch simulated rain, the soil loss was 4.5 T/A with fall plowing compared with about 0.5 T/A for fall chisel treatment or the disk treatment. Water runoff was also reduced by these two treatments which can increase water storage on sloping soils. Decreasing runoff is the most effective method of conserving water on sloping soils. Research by the USDA, ARS, and Iowa State University has demonstrated average yield increases in northwestern Iowa of 14 bushels of corn per acre from the tillage system which most effectively conserved water.

### Weed, insect, and crop disease

Potential hazards of weeds, insects, and crop diseases depend on the crop and year. While increased disease may be expected with tillage systems which leave crop residue


**The disk produces finer soil aggregates and mixes residue more thoroughly than the chisel.**

on the surface, problems are infrequent. Leaf diseases with small grain may be potentially more serious, but secondary tillage which incorporates or flattens the exposed straw may lessen the problem. Cutworms may be more severe in corn following soybeans disked or chiseled than when plowed.

### Fertility status

After chisel plowing or disking, surface-applied phosphorus, P, and potassium, K, remain in the top one-half of the tilled layer, with the greatest concentration near the surface. During a protracted drought, availability of these nutrients may decrease. Maintaining high P and K soil test levels throughout the plow layer has avoided any reduction in uptake of P and K during 5 years of Waseca trials. It seems advisable to maintain high P and K soil test levels throughout the plow layer. Moldboard plowing every 4 or 5 years should avoid the problem of positional unavailability of P and K.

### Energy and time considerations

The chisel and the disk require less energy per acre than the moldboard plow (assuming the chisel is operated at plow depth or slightly deeper and the disk working depth is less than plow depth). The plow requires about 27 horsepower-hours per acre (hp-hr/A) compared to 17 for the chisel and 12 for the disk. These estimates will vary with soil conditions. In terms of fuel required, this is equivalent to 2.1 gallons-per-acre (GPA) for moldboard plowing, 1.3 GPA for the chisel, and 0.9 GPA for the disk.

Since the chisel and the disk do less work on the soil and residues than the plow, an extra operation may be required to break up corn stalks and/or partially mix them with the soil. Chopping the stalks with a chopper or shredder ahead of the chisel helps reduce volume and chisel plugging. The disk is also effective ahead of the chisel to cut the stalks and mix some of them with the soil. This combination of operations is beneficial because it reduces the amount of residue on top of the soil. Excessive crop residue on the surface will shade the soil and lower soil temperatures in the spring. The disking operation should not be done after the chisel because it leaves the surface smoother with fine particles which are more apt to blow, wash, or seal the soil to water infiltration. The combination of chopping and chiseling or disking and chiseling requires about the same energy as moldboard plowing. Double chiseling requires more energy, does less for burying residues, and breaks up the clods too much for winter erosion control.

Time saved is another very practical reason for choosing the chisel or disk over the moldboard plow. A tractor should pull a chisel 50 percent wider than its plow, saving a third of the usual time.

## YIELD RESULTS

Corn and soybean tillage trials are available from four locations: Morris, Waseca, and Lamberton, Minnesota; and Lancaster, Wisconsin. The tillage comparisons are for 2-4 years.

The research at Morris and Lamberton was carried on jointly by the USDA, ARS, Soil and Water Conservation Laboratory at Morris, cooperating with the University of Minnesota West Central and Southwestern Experiment Stations at Morris and Lamberton, respectively. The Waseca work was conducted by the University of Minnesota Southern Experiment Station, Waseca. At Lancaster, work was conducted jointly by the University of Wisconsin, Lancaster Experimental Farm, and the University of Minnesota.

### Continuous corn tillage trials

At Waseca, on a somewhat poorly drained clay loam on a south facing 2-5 percent slope, corn yields from fall and spring chisel plowing, with one or two secondary spring tillage operations, averaged within 4 Bu/A of the comparable moldboard plowing treatments. When spring disking was the only tillage, corn yields averaged within 5 Bu/A of fall plowing. On a poorly drained clay loam at Waseca, fall chisel plowing followed just by spring disking had decreased stand and corn yield in 1975 compared to fall plowing or till planting. Unusually warm and dry weather followed planting in 1975 and excessive drying occurred in the seedbed prepared by fall chiseling. Deeper planting or smaller aggregate size provided by additional secondary tillage was needed to assure satisfactory germination on the chisel treatment.

At Lancaster on a well-drained silt loam soil low in organic matter, no yield difference was found between spring chisel plow and spring moldboard plowing. No seedbed problems occurred.

### Corn after soybeans

In 3 years at Waseca, on a poorly drained clay loam soil, average corn yields from fall chisel and spring disk tillage treatments were within 2 percent of the average yield of fall plowing. Yields from spring chisel and spring plow treatments were, respectively, 6 and 11 percent lower than fall plowing.

In 2 years at Lamberton, the average corn yield from all fall plow treatments and all chisel treatments was within 2 Bu/A. Past research at Lamberton found increased yields from fall plowing compared with spring plowing; however, this trend has not been apparent in the 2 years of the current study due to the exceptionally dry and warm weather these springs.

At Morris, on a moderately well-drained clay loam soil, 2-year average corn yields for fall chisel plowing were equal or slightly greater than for fall or spring plowing.

### Soybeans after corn

On a poorly drained clay loam soil at Waseca, 3-year soybean yields from fall or spring plowing, fall or spring chiseling, and fall or spring disking were not significantly different and the range in average yields was less than 3 Bu/A. In 2 of 3 years, no differences in early soybean growth were found in spite of mulch levels of 3 T/A of cornstalks on the surface. In 1975, early growth differences occurred, but they were not related to any differences in yield. The conclusion is that soybean yield and early growth is much less affected by mulch level or seedbed preparation than corn yield and early growth, and that early growth has not been related to soybean yields.

On a moderately well-drained clay loam soil at Lamberton, there was no significant difference in yield between fall plow and fall chisel treatments. Spring chisel and spring disk treatments were also not significantly different in yield. In 1 year, fall plowing had significantly greater yields than spring treatments. On well and moderately well-drained clay loam soils at Morris, there was no significant difference in yield between fall chisel plowing and fall and spring moldboard plowing. Yield differences were within 2 Bu/A.

## SUMMARY

Corn and soybean yields in a corn-soybean rotation have been similar for fall moldboard plowing and fall chisel plowing on soils varying from well-drained silt loam to poorly drained clay loam. With continuous corn, more difficulty in preparing a suitable seedbed in the spring on moderately fine-textured soils has occurred following fall chisel plowing than following fall moldboard plowing. It means extra care in secondary tillage may be necessary following chisel plowing to assure a satisfactory seedbed on clay loam and finer-textured soils. On soybean ground with no fall tillage, spring disking frequently gives superior seedbeds when compared with spring moldboard or chisel plowing on poorly drained clay loam and finer-textured soils.

Avoid heavy levels of mulch on the surface of poorly drained soils. Levels of 2 T/A mulch have not decreased corn yields on a south facing somewhat poorly drained soil, but 4 T/A mulch (with no-till corn) reduced yields 10 Bu/A. On poorly and very poorly drained soils, mulch levels must be very carefully regulated to avoid corn yield reductions.

Chisel plowing or disking

- can decrease time and fuel use,
- allows crop residues to be used for water and/or wind erosion control, and sometimes water conservation,
- requires careful monitoring of fertility, weed, insect, and crop disease problems.

Chisel plowing

- generally results in stands and yields similar to fall plowing, but some stands are reduced,
- may require additional secondary tillage or some modification of secondary tillage practices in certain years to provide a satisfactory seedbed on poorly drained clay loam and finer-textured soils.

Disking

- leaves the soil finer and more susceptible to wind and water erosion,
- is effective for cutting and mixing crop residues with the soil.

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